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ATTENUATION MEASUREMENTS OF EAR MUFFS AT FRASER MINE 1984

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by

M.U. Savich* and J.K. Weglo**

ABSTRACT

Ear muffs are the main protection of the mining workforce for the attenuation of noise.

The measurement of head size as against clamping force as well as the condition of the ear muffs are demonstrated as important variables in this attenuation of noise.

The "NO NOISE" ear muffs attenuation was about 13.3 dBA average with a Standard Deviation of 4.8 dBA at the Fraser Mine.

The Mark V ear muffs, replacing those in this study, based on clamping force measurements versus head size can be expected to produce attenuation >14 dBA.

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MESURE DU DEGRÉ DE RÉDUCTION DU BRUIT DES SERRE-TÊTES À LA MINE FRASER, 1984

par

M.U. Savich* et J.K. Weglo**

RÉSUMÉ

Les serre-têtes sont utilisés comme principale protection contre le bruit par les travailleurs des mines.

La mesure des dimensions de la tête par rapport au dispositif de fixation de même que la condition des serre-têtes sont des variables importantes de l'amortissement du bruit.

À la mine Frazer, le niveau d'amortissement "aucun bruit" des serre-têtes était en moyenne de 13,3 dBA et l'écart-type était de 4,8 dBA.

Les serre-têtes Mark V qui ont remplacé ceux qui avaient été utilisés aux fins de la présente étude et qui sont fabriqués d'après des critères de fixation par rapport aux dimensions de la tête auront probablement la capacité d'amortir le bruit à >14 dBA.

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CONTENTS

	Page
ABSTRACT	i
RESUME	ii
INTRODUCTION	1
MEASUREMENTS AND RESULTS	1
Head Size and Clamping Force	3
Attenuation Measurements	10
CONCLUSIONS	15
ACKNOWLEDGEMENTS	15
REFERENCES	16
APPENDIX A	A-17
APPENDIX B	B-18
APPENDIX C	C-19
APPENDIX D	D-20
APPENDIX E	E-21

FIGURES

No.		
1.	The normal symmetrical frequency of bell-shaped curve of head size tests	4
2.	The clamping force frequency curve skewed to the right	6
3.	Relationships between head size and clamping force at the Fraser Mine	8
4.	Standard deviation ellipse of "NO NOISE" muffs	9

TABLES

1.	Attenuation characteristics of ear muffs acquired for testing.	2
2.	Summary of head size tests	5
3.	Comfort of ear muffs in mines	13
4.	Comparison of peak levels in the different mines using different instrumentation for evaluation	14

INTRODUCTION

As part of the ongoing program of reducing noise pollution at Falconbridge Mines, measurements were performed to test the efficiency of ear muffs which were being used there.

At the Fraser Mine the following ear muffs were tested:

1) "NO NOISE", model NN3-F, the Hellberg Standard Volume Hearing Protector, hard hat attachment;
2) Mark IV, MSA, worn behind the head;
3) Mark V, Ear cup kit, MSA hard hat attachment;
4) David Clark, model E-705 straightaway;
5) Bilsom Viking muff 2314, hard hat attachment; and
6) Peltor H7P3e, hard hat attachment.

Most of the analyses were done on "NO NOISE" ear muffs, model NN3-F, because they were the ones most commonly used by over 90% of the workforce. The framework and method, followed by theoretical and practical considerations, are described in the main report and should be read to compare Fraser with other Falconbridge Mines.

Fifty-seven tests of head size and clamping force were made and 25 attenuation tests were performed on the "NO NOISE" ear muffs. On the Mark IV muffs 3 attenuation tests were done, and 2 such tests on David Clark muffs. Only one test was performed on each of the other brands. Attenuation characteristics of all ear muffs are given in Table 1. Noise Reduction Ratings (NRR) given in this Table are those supplied by manufacturers and from this data all muffs are approximately equal.

MEASUREMENTS AND RESULTS

Tests were performed using Metrosonics instrument, type db-307. The

Table 1 - Attenuation characteristics of ear muffs acquired for testing (ANSI S3.19-1974).

No.	Ear Muff	Characteristic	Frequency Hz									NRR
			125	250	500	1000	2000	3150	4000	6300	8000	
1	"NO NOISE" Model NN5-F Hellberg	Mean	16.2	19.9	25.2	34.1	36.0	39.2	39.0	40.3	38.1	24
		Std. Dev.	2.5	1.8	2.0	1.7	2.2	3.1	2.0	4.0	4.1	
2	Mark IV MSA	Mean	17.0	18.0	29.0	36.0	38.0	44.0	44.0	43.0	43.0	24
		Std. Dev.	2.6	2.6	3.1	3.2	4.1	7.2	4.6	4.7	5.7	
3	Mark V MSA Hard hat attachment	Mean	14.9	20.2	28.2	35.0	33.4	35.4	33.5	33.1	32.2	24
		Std. Dev.	2.6	1.5	1.9	2.5	2.1	2.8	2.6	2.7	3.0	
4	David Clark Model E-705 Straightaway	Mean	12.0	17.0	30.0	35.0	35.0	36.0	37.0	32.0	30.0	-
		Std. Dev.	2.5	3.0	4.6	5.6	4.5	4.3	4.2	4.1	2.9	
5	Viking Muff No. 2314 Bilsom	Mean	15.0	21.0	27.0	37.0	36.0	38.0	42.0	42.0	39.0	25
		Std. Dev.	1.8	2.0	2.5	2.8	1.5	2.3	3.0	3.7	3.6	
6	Peltor H7P3e	Mean	14.1	18.8	28.1	36.2	35.6	38.4	35.0	35.5	36.4	24
		Std. Dev.	2.1	2.0	3.0	2.1	2.2	2.3	2.1	2.1	2.4	

instrument measures sound over the continuous range of 45 to 140 dBA. Its microprocessor continuously samples and displays dBA sound levels while calculating L_{max}, L_{peak} and test duration. Testing should be done using 4 dosimeters rather than 3, as we have done. This would simplify and speed up testing time. It is very time-consuming and difficult to reset from OSHA (doubling at 5 dB) to ISO (doubling at 3 dB) in most work areas. Cables and microphones should be small in size in order to avoid creating an opening that would cause leakage of sound at the point where they enter the muff (breaking the seal between muff and face). It was found to be very difficult at times to position microphones comfortably inside ear muffs. Workers had a tendency to want to adjust their ear muffs while the test was being conducted which sometimes caused leakage and forced a repeat of the test.

Conducting tests on workers using fixed equipment (such as [I.T.H.] in the hole drills, jumbo drills and diamond drills) was much simpler, providing workers didn't encounter problems with their equipment and were willing to cooperate. Testing where workers use man-handling equipment such as jack legs - stopers, scooptrams and mucking machines was more difficult.

Head size was measured with outside calipers, and clamping force with a manual balance.

HEAD SIZE AND CLAMPING FORCE

Head size and clamping force tests were performed only on "NO NOISE" ear muffs. Summary results of head size and clamping force tests are in Appendix A.

The head size frequency curves of clamping force tests on population - 57, and of attenuation tests on population - 23, were constructed in Figure 1. On the basis of population - 57 data, a negatively skewed curve is obtained because heads in this sample were of consistently small bizygomatic diameter.

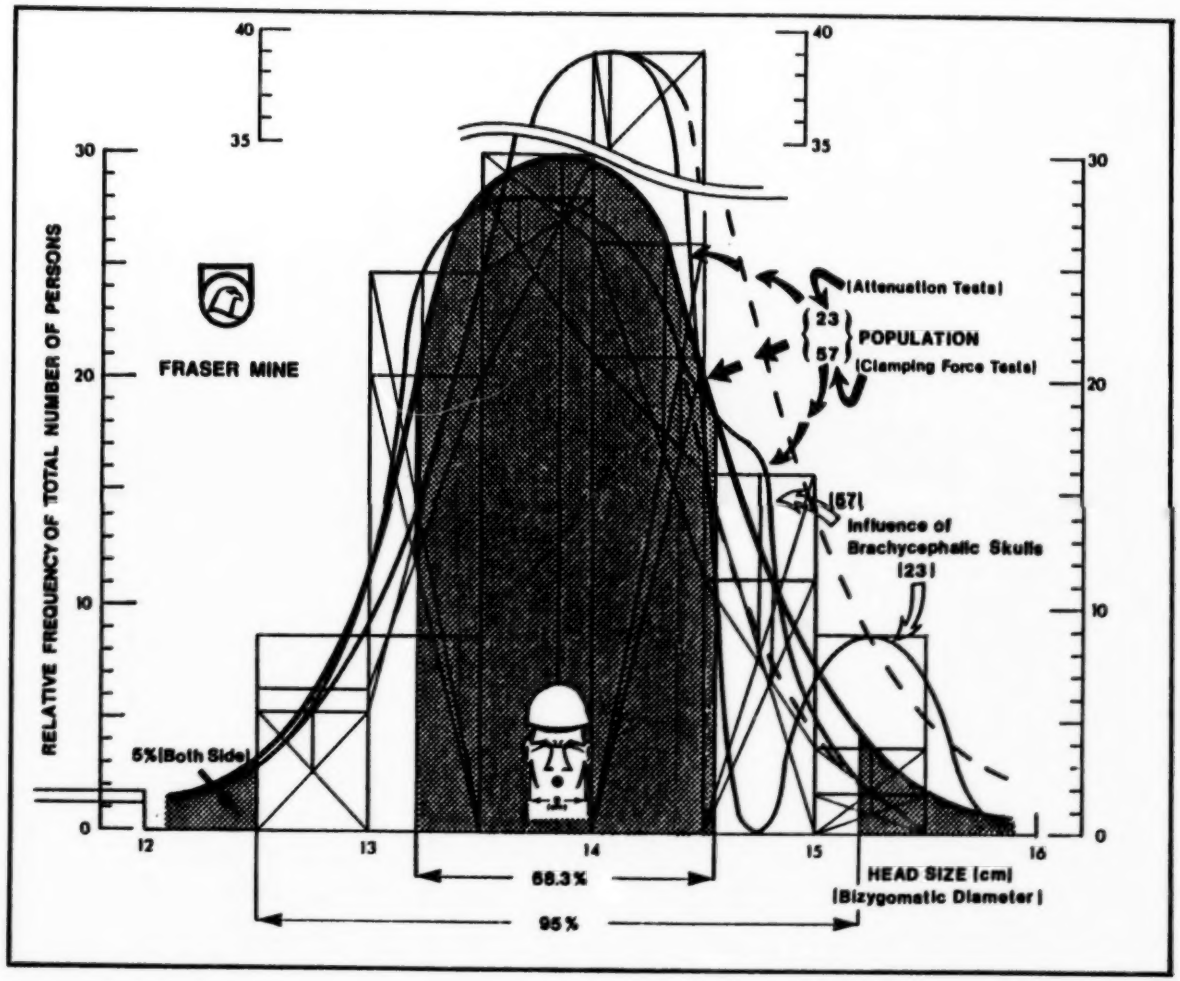

Fig. 1 - The normal symmetrical frequency of bell-shaped curve (population - 80) of head size tests. The negative skewness curve (population - 57) has a hump-influence of brachycephalic skulls. The bimodal frequency curve has two maxima (population - 23): the first maximum is typical positive skewness; and the second maximum is on large-sized heads.

The sample population contained many persons of French origin. Such people, specifically those whose ancestors came from Normandy and other Atlantic regions of France, tend to have small heads. A more marked variation of head dimensions occurs with a smaller population during attenuation tests. When test results are performed on a large population a normal symmetrical frequency, or bell-shaped curve, is obtained. Large population samples are necessary to allow proper evaluation.

By simply calculating the above-mentioned curve nuances cannot be noticed (Table 2).

Table 2 - Summary of head size tests

No.	Test	N	cm		Confidence Limit, cm	
			Mean	Std. Dev.	90%	95%
1	Head size and clamping force	57	13.64	0.77	13.64±0.16 cm	13.64±0.19 cm
2	Attenuation	23	13.76	0.62	13.76±0.22 cm	13.76±0.26 cm
1-2	Σ	80	13.67	0.73	13.67±0.13 dBA	13.67±0.15 dBA

Population → ← Grand Mean

In this Table we can see that confidence limits are high, and that at this mine heads of small bizygomatic diameter are most prevalent. Measurements of head size and clamping force were repeated twice because of the author's bias, which was formed on the basis of literature data and his own measurements (for North America the average head size is 14.35 cm).

The clamping force frequency curve has negative skewness (skewed to the left, but only slightly) (Figure 2). It can almost be said that the curve is symmetrically normal. From the clamping force frequency curve it can be concluded that 82% of the work force has a clamping force stronger than 1000 gwt, which is good as far as attenuation is concerned. Ear muff damage was

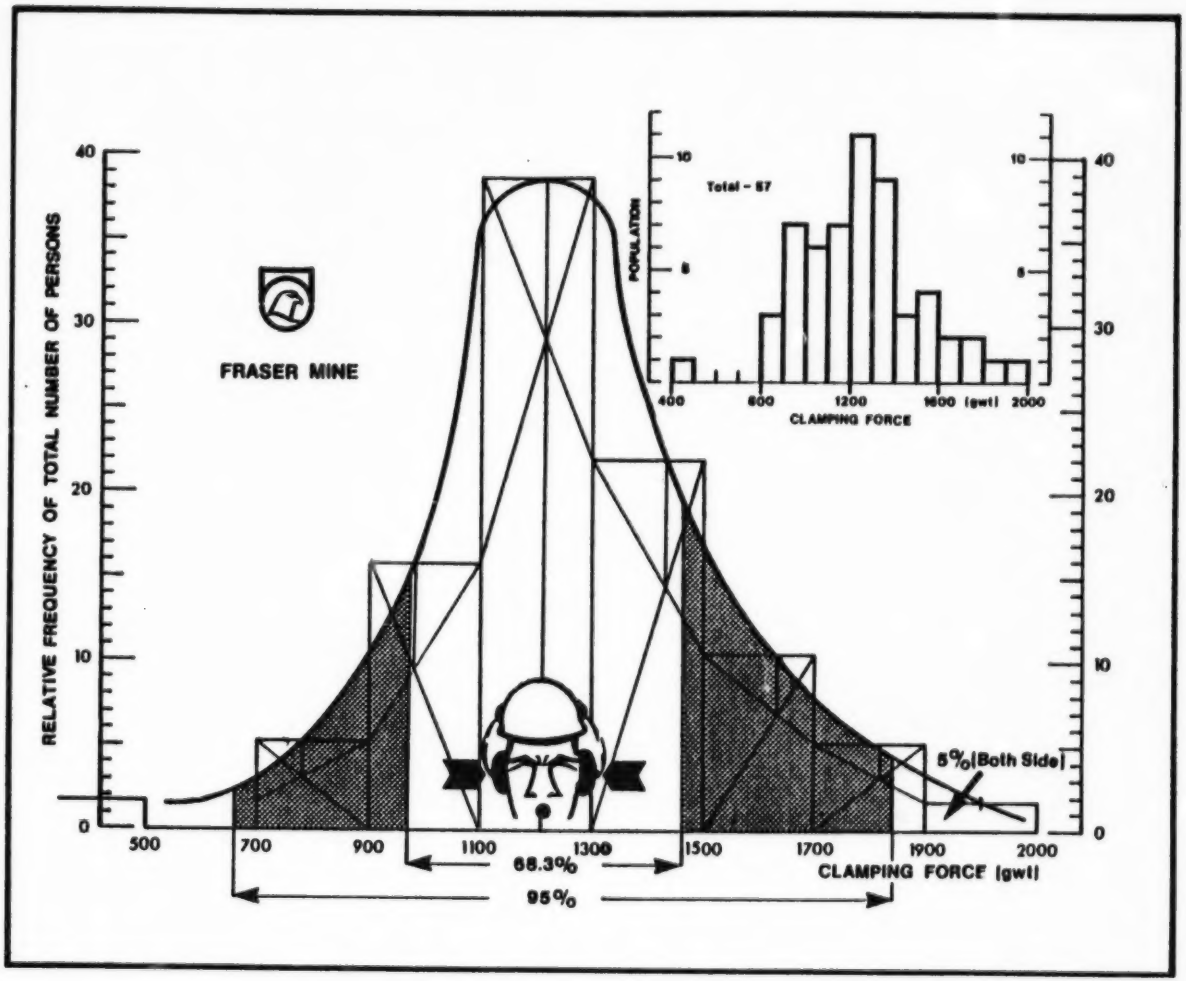

Fig. 2 - The clamping force frequency curve skewed to the right (positively skewed).

not heavy in relation to population, but was significant because of the high standard deviation (Figure 3). Most deterioration occurs with small heads (13.00 to 13.50 cm). These are two possible reasons for this: either ear muffs are not efficient on small heads, or clamping force is too strong, forcing workers to 'adjust' it for comfort, thus damaging muff springs. The second explanation is more likely, because standard deviation is high. The same thing occurs when head size is from 14.50 to 15.00 cm. Clamping force does not increase progressively with head size. Data from Appendix A was used to construct a standard deviation (error) ellipse (Figure 4). From this construction we can see that the ellipse in large part covers the field of clamping force versus head size; and therefore, we can expect good attenuation.

Utilization of the OSHA prescribed methods of estimating the adequacy of hearing protector attenuation, requires the availability of the manufacturers' published Noise Reduction Rating (NRR) and/or octave band attenuation data at the frequencies from 125 Hz to 8 kHz (1). This estimation method will be used in all reports. Results obtained will be compared with the results of measurements taken at this and other mines.

Condition of ear muffs were extremely good.

Ear Muffs	N*	Condition of Muffs					
		Good		Fair		Poor	
		N_1	Percent	N_2	Percent	N_3	Percent
"NO NOISE"	57	49	85.96	7	12.28	1	1.75

Note: * Population ($N^* = N_1 + N_2 + N_3$)

While tests were being done all minor damage was repaired and ear cushions were replaced.

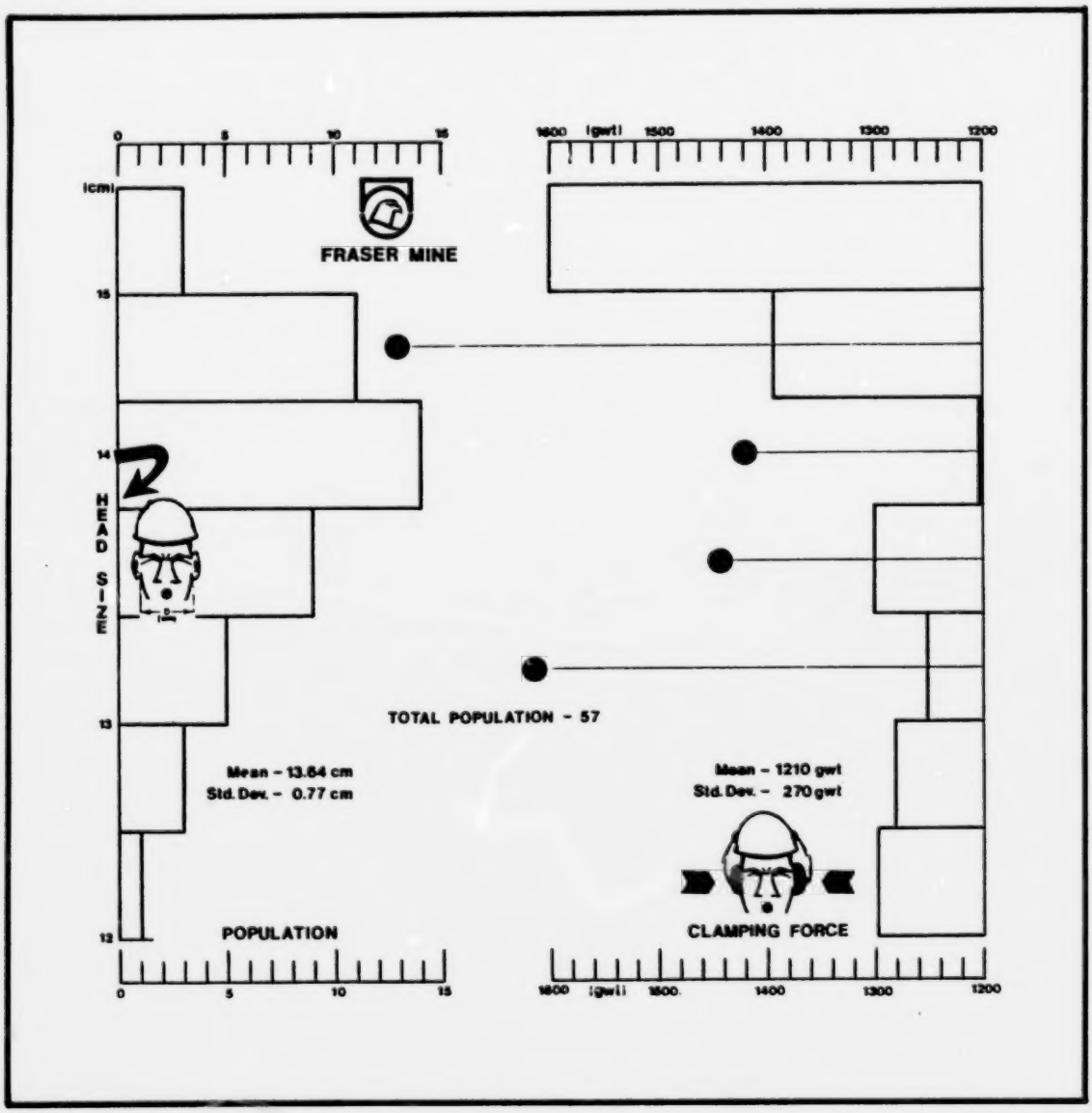

Fig. 3 - Relationships between head size and clamping force at the Fraser Mine.

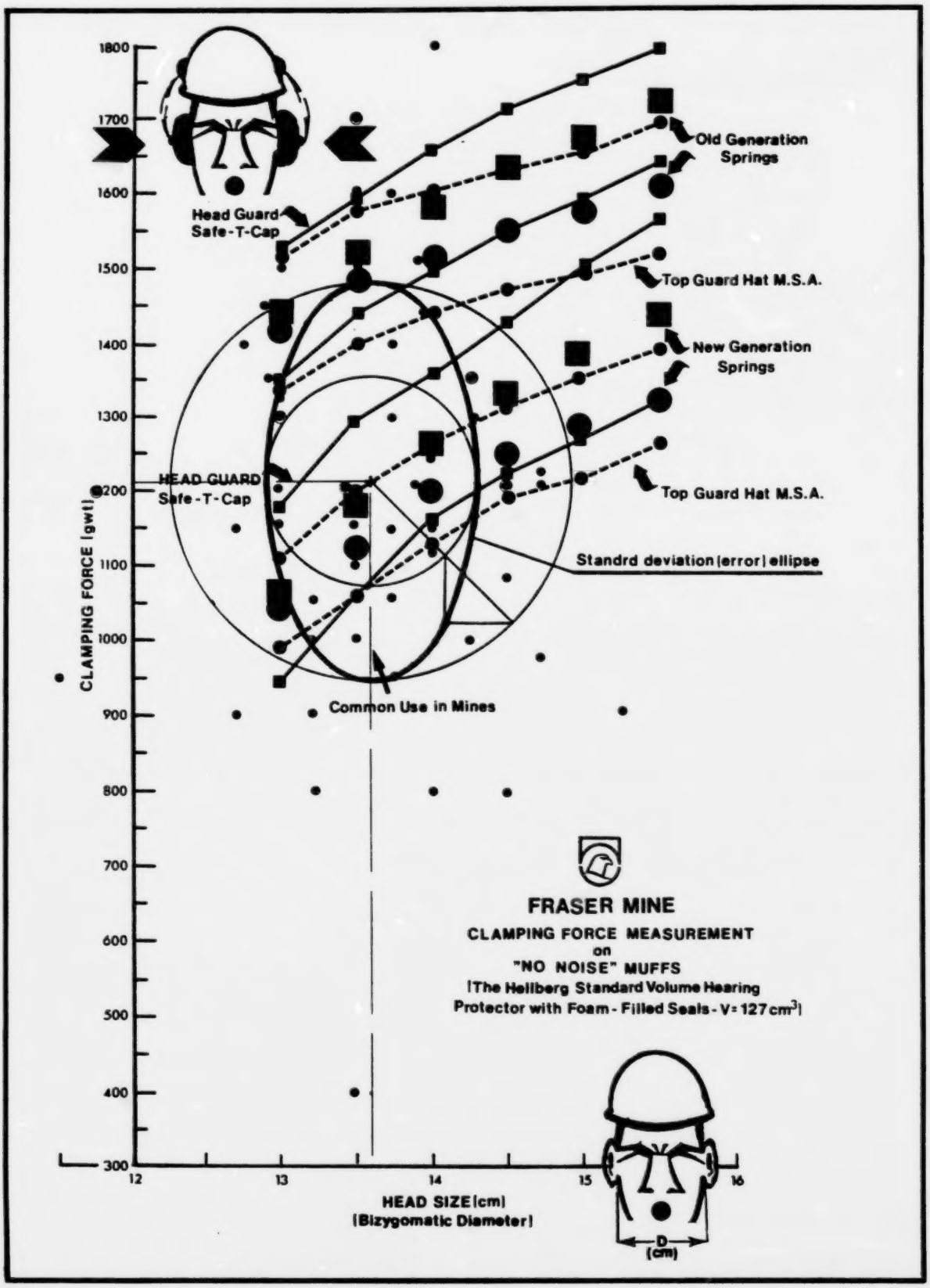

Fig. 4 - Standard deviation (error) ellipse of "NO NOISE" muffs.

ATTENUATION MEASUREMENTS

Attenuation measurements were performed on the following ear muffs:

1) "NO NOISE", model NN3-F, 25 measurements were made in OSHA mode, and 25 measurements in ISO mode (Appendices B and C);
2) Mark IV, MSA, 3 measurements in OSHA mode, and 3 measurements in ISO mode (Appendices D and E).
3) Mark V, MSA, 1 measurement in OSHA mode, and 1 meaurement in ISO mode (Appendices D and E).
4) David Clark, model E-705, 2 measurements in OSHA mode, and 2 measurements in ISO mode (Appendices D and E).
5) Bilsom Viking muff 2314, 1 measurement in OSHA mode, and 1 measurement in ISO mode (Appendices D and E).
6) Peltor H7P3e, 1 measurement in OSHA mode, and 1 measurement in ISO mode (Appendices D and E).

Testing was carried out on various types of equipment (e.g., Joy jacklegs and stopers, Gardner Denver jumbo drills, in-the-hole ITH drills, mucking machines and scooptrams. A total of 33 tests were conducted.

Tests of "NO NOISE" ear muffs show the following attenuations (Appendices B and C):

Mode	dBA		Confidence Limit	
	Mean	Std. Dev.	90%	95%
OSHA	12.68	6.82	12.68$\pm$2.32 dBA	12.68$\pm$2.80 dBA
ISO	13.29	4.83	13.29$\pm$1.69 dBA	13.29$\pm$1.98 dBA

In both modes we get results which are approximately equal. For the 90% ISO mode confidence limit, the result differs by $\pm$1 dBA; and for the 95% limit there is essentially no difference between OSHA and ISO modes.

At the Fraser Mine almost 90% of the miners wear "NO NOISE" ear muffs, which have a small cup size. Workers with large ears, who are quite common, find microphones in their muffs very annoying and claim that they cause an increase in noise levels. It is important, when positioning a microphone in the muff, to take a noise reading (trial run) and re-adjust the muff if necessary. Workers should be instructed not to adjust their muffs until the test has been completed. At times when a worker is working hard physically (lots of bending and reaching) in operating his equipment, adjustment is more frequent and more leakage occurs. Other muffs, such as Mark IV, Mark V, David Clark, Bilsom and Peltor, have a large cup which helps to avoid this problem. Because of the small number of attenuation tests performed on these muffs, the muffs cannot be fully evaluated. All indications, however, are that they show better attenuations:

N	dBA		Confidence Limit	
	Mean	Std. Dev.	90%	95%
7	16.27	4.75	16.27±3.25 dBA	16.27±4.14 dBA

Population

From the 7 measurements carried out on the other types of ear muffs, we can see that the lowest values are 13.02 dBA (90% confidence limit) and 12.13 dBA (95% confidence limit), which is approximately the same as "NO NOISE" ear muffs. The highest values are 19.52 dBA (90% confidence limit) and 20.41 dBA (95% confidence limit), which is high if one considers that they have the same NRR as the "NO NOISE" model NN3-F ear muffs (Table 1).

Comfort did not receive all that good a rating. This is to be expected because the error ellipse points to a strong clamping force of ear muffs (Figure 4). Comfort results are given in Table 3. From these results the following can be concluded: 76% of workers deemed "NO NOISE" muffs to have

satisfactory comfort. If we compare this figure to the error ellipse (Figure 4), we see that 80.6% of the ellipse's area covers the field of head size versus clamping force. Here too, comfort and clamping force do not go hand in hand, showing an increasing relationship:

"NO NOISE" Ear Muffs	Comfort	○ -Satisfactory 75.9%	◒ -Good 24.1%
	Area rating error ellipse	Non-Coverage 14.4%	Coverage 80.6%

The same conclusion was reached at Falconbridge and Strathcona Mines.

Measurement results from Appendices B and C, and the Lockerby Mine were used to compute L_{max} and L_{peak} levels which were then compared with measurement results from Falconbridge and Strathcona Mines (Table 4). Measurements at the latter two mines were performed with an integrating sound level meter, Brüel and Kjaer, type 2225. However, measurements at the Fraser and Lockerby Mines were performed with a Metrosonics db-307 instrument. Instrument control was done to find means of standard deviations of L_{max} and L_{peak} (accuracy of measurement field test). Results should be approximately the same. However, with Fraser and Lockerby Mines' measurements they differ considerably, by 7 dBA and do not allow for L_{peak} comparison. L_{ave} is measured well by the instrument (slow-speed chips).

In Appendix C the data shows how attenuation falls because of the slowness of the processing chips in the instrument.

N	Characteristic	Attenuation (dBA)		
		L_{ave}	L_{max}	L_{peak}
25	Mean	13.29	11.45	9.03
	Std. Dev.	4.83	4.72	8.94
25	Confidence Limit 90%	13.29±1.64	11.45±1.60	9.03±3.04
25	Confidence Limit 95%	13.29±1.98	11.45±1.93	9.03±3.65

↑ Population

Table 3 - Comfort of ear muffs in mines

No.	Ear Muff	N*	○-Satisfactory		◒-Good		●-Very Good	
			N_1	Percent	N_2	Percent	N_3	Percent
1	"NO NOISE" (NN3-F)	29	22	75.9	2	24.1	0	0.0
2	Mark IV MSA	3	2	66.7	1	33.3	0	0.0
3	Mark V MSA	1	0	0.0	1	100.00	0	0.0
4	David Clark Model E-705	2	0	0.0	1	50.0	1	50.0
5	Bilsom, Viking 2314	1	0	0.0	0	0.0	1	100.0
6	Peltor, H7P3e	2	0	0.0	1	100.00	1	0.0
1-6	Σ	38	24	63.2	11	28,9	3	7.9

Note: * Population ($N^* = N_1 + N_2 + N_3$)

Table 4 - Comparison of peak levels in the different mines using different instrumentation for evaluation

Falconbridge - Strathcona Instrument: Bruel and Kjaer Integrating Sound Level Meter Type 2225.							Fraser - Lockerby Instrument: Metrosonics db-307 Noise Dosimeter and Integrating Sound Level Meter.				
		dBA					dBA				
No.	Sound Source	L_{max} Mean Std. Dev.	L_{peak} Mean Std. Dev.	Δ	N		L_{max} Mean Std.Dev.	L_{peak} Mean Std.Dev.	Δ	N	Comments
1	Jack Leg Drill	118.65 3.36	134.85 5.68	16.3	11		121.43 2.35	148.0 0.0	26.6	9	In $Mean_{SD}$, value not included
2	Stoper Drill - Rock Bolter	118.51 5.92	135.0 7.0	16.5	22		118.48 1.65	141.92 6.22	23.4	18	
3	Jumbo Drill - two booms	116.96 5.91	122.14 3.91	15.19	8		109.02 1.03	136.85 10.47	27.8	15	
4	Long Hole Drill	119.19 1.98	135.08 2.59	15.89	4		116.06 2.79	141.12 6.87	25.06	5	
5	Long Tom Drill - two booms	120.27 2.99	137.17 4.63	16.9	23		-	-	-	-	
6	ITH In the Hole Drill	98.27 5.12	116.25 5.66	17.98	7		101.06 5.79	121.65 18.36	20.59	37	
7	Diamond Drill	104.02 4.76	120.81 9.93	16.79	7		108.6 1.77	133.74 11.90	25.14	18	
8	Mucking Machine	106.58 3.60	121.53 3.53	14.95	4		109.97 0.51	147.26 1.18	37.29	5	
9	Bolting Machine	-	-	-	-		110.55	147.0	36.4	1	
10	Air Plugger (Brk. Cement)	-	-	-	-		112.20 0.57	148.0 0.0	35.8	2	In $Mean_{SD}$, value not included
11	Slusher	97.50 4.99	111.35 4.45	13.85	4		115.30 1.27	148.0 0.0	32.7	2	In $Mean_{SD}$, value not included
12	Scooptram	106.55 14.57	123.33 11.80	16.78	12		108.18 5.22	142.12 9.38	33.94	16	
13	Conveyor Man	94.83 6.40	112.15 8.35	17.32	3		-	-	-	-	
14	Chute Puller	114.80 9.19	133.15 3.32	18.35	2		-	-	-	-	
15	Vent. Fan - 38" 60 HP	-	-	-	-		100.48 5.10	117.91 14.12	17.43	4	
16	Primary Crusher - U/G Jaw Crush.	102.34 6.93	121.56 8.24	19.22	8						
17	Secondary Crusher	91.77 1.33	106.27 1.62	14.5	3						
18	Tertiary Crusher	95.45 0.21	108.35 0.64	12.9	2						
19	Ball Mill	93.20 2.02	107.57 1.16	14.37	3						
20	Flotation Op. Area	85.9	99.3	13.4	1						
21	Compressor Room	89.7	103.0	13.3	1						
22	Power House	94.5	107.5	13.0	1						
23	Electrostatic Precipitator	93.65 0.35	109.20 3.82	15.55	2						
24	Converter Puncher	99.13 1.10	114.27 1.79	15.14	3						
25	Converter Skimmer - Fluxing	89.47 4.76	103.82 4.91	14.36	3						
		$Mean_{SD}$ Std.Dev.	$Mean_{SD}$ Std.Dev.				$Mean_{SD}$ Std.Dev.	$Mean_{SD}$ Std.Dev.			
		4.51	5.00				2.98	9.81			
		◇19 3.45	3.04	19◇			◇8 2.09	5.25	8◇		

Laboratory tests of measurement accuracy were performed at Laval University and their conclusion agrees with the one above (2). This explains why L_{max} and L_{peak} of Fraser and Lockerby Mines were not presented to the main report for Falconbridge Ltd.

CONCLUSIONS

Measurements have shown that the attenuation of "NO NOISE" ear muffs was about 13 dBA. Ear muff efficiency depends on the frequency range of noise. The overall condition of ear muffs was satisfactory because only 2% of them were deemed to be in poor condition. Workers should continue to be trained to understand the importance of a proper fit for ear muffs. Head shapes and sizes had a marked effect on attenuation. Physical obstructions, such as eye glasses and large ears decreased attenuation. From the attenuation measurements it can be concluded that ear muffs in themselves are not a complete solution to the attenuation of the noise level in the mining environment.

Ear muff control should be continued, by measuring head size and clamping force with the apparatus suggested in the main report.

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Thanks are extended to G. Knight for reviewing the manuscript and making numerous helpful suggestions.

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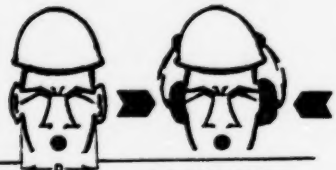
Head size and clamping force data of "NO NOISE", Model NN3-F ear muffs.



No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Driller	1	11.75	1200
2	Driller	1	11.50	950
3	Driller	1	11.25	1200
4	Driller	1	14.25	1350
5	Driller	1	13.00	1350
6	Driller	1	13.50	1200
7	Driller	1	13.25	1050
8	Driller	2	13.75	950
9	Driller	1	13.50	1000
10	Driller	1	14.50	1400
11	Driller	1	13.00	1300
12	Raise Driller	1	13.25	1325
13	Raise Driller	1	13.25	1325
14	Raise Driller	1	13.25	1150
15	Blast Hole Drill.	1	14.25	900
16	JTH Drill.	1	13.00	1500
17	Diamond Drill	3	13.50	400
18	Diam. Drill Form.	1	15.25	900
19	Long Hole Blast.	1	14.00	1200
20	Blaster Helper	1	13.75	1150
21	Gunite Operator	1	13.75	1300
22	Gunite Operator	1	13.25	1000
23	Gunite Operator	1	14.50	800
24	Gunite Operator	2	14.00	1100
25	Nipper	1	14.00	1500
26	Trammer	1	15.00	1450
27	Trammer	1	13.50	1500
28	Trackman	1	13.00	1300
29	Pipe Fitter	1	14.25	1300
30	Pipe Fitter	1	13.50	1700
31	Scooptram Op.	2	12.75	900
32	Scooptram Op.	1	14.75	1225
33	Scooptram Op.	1	14.50	1100
34	Scooptram Op.	2	14.00	1250
35	Scooptram Op.	2	14.00	800
36	Construction	2	13.50	1100
37	Construction	1	14.75	975
38	Construction	1	13.25	1000
39	Construction	1	14.50	1200
40	Construction	1	13.50	1600
41	Construction	1	14.00	1800
42	Construction	1	14.50	1200
43	Construction	1	13.50	1700
44	Lev. Cleaner	1	13.25	800
45	Lev. Cleaner	1	13.75	1400
46	Lev. Cleaner	1	14.75	1200
47	Cage Tender	2	14.25	1000
48	Cage Tender	1	13.75	1600
49	Training	1	13.50	1150
50	Training	1	13.25	900
51	Shift Boss	1	14.00	1500
52	Shift Boss	1	13.75	1050
53	Shift Boss	1	13.00	1200
54	Shift Boss	1	12.75	1150
55	Safety Superv.	1	13.50	1200
56	Ground Control	1	14.50	1900
57	Ventilation	1	14.25	1350
	Mean:		13.64	1210
	Std. Dev.:		0.77	279

Note: 1 - Good; 2 - Fair; 3 - Poor.

Attenuation tests of "NO NOISE" model NN3-F muffs in OSHA mode.

No.	Equipment	Comfort		L. Avg. (dBA)	Attenuation (dBA)			L. Max. (dBA)	Attenuation (dBA)			L. Peak (dBA)	Attenuation (dBA)			Location
					L.S.	R.S.	B.S.		L.S.	R.S.	B.S.		L.S.	R.S.	B.S.	
1	Jack Leg AL-60 Drill	○	14.0	114.85	7.0	2.9	4.95	120.1	7.7	2.8	5.25	148.0	4.3	11.4	7.85	3400 Level, 2-560 Stope
2	Stoper Dr.-Rock Bltg.	◒	13.5	113.5	13.8	9.7	11.75	119.4	7.8	4.5	6.15	136.2	3.4	6.1	4.75	3300 Level, Sublevel
3	Stoper Dr.-Rock Bltg.	○	-	107.15	14.9	4.3	9.6	116.15	10.3	2.2	6.25	135.15	3.1	-	1.55	3400 Level, 547-1 Stope
4	Stoper Dr.-Rock Bltg.	○	-	110.65	7.4	8.6	8.0	117.9	8.1	18.4	13.25	148.6	18.9	16.3	17.6	2900 Level, 285 Vent. Drift
5	Stoper Dr.-Rock Bltg.	○	-	116.5	12.6	2.7	7.3	120.9	15.4	1.3	8.35	148.0	17.7	7.1	12.4	2900 Level, 285 Vent. Drift
6	Jumbo Drill	◒	12.75	103.8	12.8	20.6	16.7	107.7	12.7	18.4	15.55	127.5	5.0	4.3	4.65	3300 Level, 552-54 Stope
7	Jumbo Drill	○	13.75	105.25	26.6	24.3	25.45	109.75	11.8	25.4	18.6	139.0	5.3	15.9	10.6	3400 Level, 558 Stope
8	Jumbo Drill	○	14.25	105.9	23.8	19.8	21.8	108.95	25.2	18.4	21.8	135.95	3.9	15.3	9.6	3400 Level, 558 Stope
9	Jumbo Drill	○	13.0	106.2	23.2	10.7	11.45	108.3	12.0	9.6	10.8	148.0	26.3	24.3	25.3	3400 Level, 543 Stope
10	Jumbo Drill	◒	14.0	102.5	4.2	5.3	4.7	109.35	8.0	9.5	8.75	148.0	25.2	26.0	25.6	3300 Level, 556 Stope
11	Jumbo Drill	○	14.0	105.3	18.0	10.0	14.0	109.1	21.6	9.7	15.65	141.05	16.7	13.6	15.15	3300 Level
12	Long Hole Drill ITH	◒	13.5	94.6	16.9	20.2	18.6	95.0	7.5	3.5	5.5	121.5	0.9	1.8	1.35	3400 Level, Waste Pass
13	Long Hole Drill ITH	○	13.5	94.5	26.1	5.4	15.7	97.25	9.0	6.2	7.6	148.0	26.0	22.6	24.3	3300 Level,302 Sublevel,556 Over Cut
14	Diamond Drill	◒	14.25	104.9	1.1	0.9	2.0	110.4	4.2	1.9	3.05	129.0	5.1	3.4	4.25	3300 Level,1 Cross Cut,Cl. Force 400 gwt.
15	Diamond Drill	◒	12.5	104.3	28.6	21.7	25.15	107.3	18.5	8.0	13.25	120.3	0.5	0.2	0.35	300 Level, 287 E. Drift
16	Diamond Drill	○	13.75	103.9	25.5	29.8	27.6	106.85	10.6	18.3	14.45	122.3	-	4.6	2.3	3300 Level, 287 E. Drift
17	Diamond Drill	○	-	109.0	13.4	14.9	14.1	112.0	9.2	1.9	5.55	124.2	1.0	3.1	2.05	3300 Level, 275 Drift
18	Diamond Drill-Foreman	○	15.0	104.85	11.7	8.7	10.5	108.7	8.3	3.3	5.75	123.3	0.7	3.8	2.5	3300 Level,1 Cross Cut,Cl. Force 900 gwt.
19	Air Plugger(Brk.Cement)	○	13.5	106.3	7.6	8.1	7.8	111.85	6.4	5.9	6.15	148.0	19.7	16.4	18.05	3400 Level Station
20	Bolting Machine	○	13.25	104.1	22.9	10.1	16.5	106.25	11.0	10.4	10.7	144.0	20.0	11.7	10.85	3400 Level, 360 Stope
21	Mucking Machine	○	-	99.5	5.9	10.0	7.9	110.55	4.5	8.2	8.95	147.0	12.1	13.3	12.7	2900 Level, Vent. Drift
22	Scooptram S.T. 8	○	14.0	96.2	9.6	8.0	8.8	104.45	5.3	5.5	5.4	132.6	2.6	4.4	3.5	3400 Level, 564 Over Cut
23	Scooptram S.T. 8	○	14.25	97.2	8.0	7.6	7.8	105.4	8.3	6.5	7.4	130.15	5.9	0.4	3.15	3400 Level, 564 Over Cut
24	Scooptram S.T. 8	○	-	97.2	7.2	9.5	8.3	105.85	7.3	7.7	7.5	148.0	20.2	20.1	20.15	3400 Level, 552-2 Stope
25	Vent.Fans 38" 7.0 H.P.	○	13.75	95.1	13.3	7.8	10.55	96.8	4.9	4.3	4.6	96.75	2.9	8.8	5.85	3400 Level, 34-278 Ramp
	Mean:		13.71	104.11	14.04	11.24	12.68	109.04	10.22	8.47	9.45	135.6	9.9	10.20	9.86	
	Std. Dev.:		0.58	6.12	7.71	7.43	6.82	6.64	5.19	6.47	4.82	12.94	9.2	7.89	8.08	

Note: ○ Satisfactory; ◒ Good; ● Very Good.

Attenuation tests of "NO NOISE", model NN3-F muffs in ISO mode.

No.	Equipment	Comfort		L Avg. (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	L Max. (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	L Peak (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	Location
1	Jack Leg AL-60 Drill	○	14.0	120.6	14.3	8.6	11.4	123.6	14.1	7.0	10.55	140.8	7.4	3.6	5.5	3400 Level, 2-560 Stope
2	Stoper Dr.-Rock Bltg.	◒	13.5	-17.3	13.9	21.4	17.6	119.5	14.1	19.3	16.7	137.4	8.3	13.0	10.65	3300 Level, sub-level
3	Stoper Dr.-Rock Bltg.	○	-	114.8	20.1	17.4	18.7	119.2	10.3	11.6	10.8	135.9	10.0	5.2	7.6	3400 Level, 547-1 Stope
4	Stoper Dr.-Rock Bltg.	○	-	112.9	4.0	6.4	5.2	117.5	9.3	5.6	7.45	148.0	22.2	15.2	18.7	2900 Level, 285 Vent. Drift
5	Jumbo Drill	◒	12.75	110.0	14.2	13.8	14.0	107.8	12.2	12.9	12.5	123.6	3.2	4.4	3.8	3300 Level, 552-54 Stope
6	Jumbo Drill	○	13.75	104.6	20.1	20.7	20.4	107.8	20.0	19.5	19.75	121.0	0	0	0	3400 Level, 558 Stope
7	Jumbo Drill	○	14.25	106.7	14.8	20.7	17.7	108.2	19.1	17.4	18.25	128.7	8.4	4.3	6.35	3400 Level, 558 Stope
8	Jumbo Drill	○	13.0	106.5	12.8	16.8	14.8	109.95	14.6	13.2	11.9	148.0	26.3	28.0	27.15	3400 Level, 543 Stope
9	Jumbo Drill	◒	14.0	104.2	13.3	9.6	11.4	110.1	5.0	11.9	8.4	148.0	27.6	28.0	27.8	3300 Level, 556 Stope
10	Jumbo Drill	○	14.0	105.5	19.8	9.7	14.7	109.3	11.2	10.9	11.0	126.6	9.0	4.3	6.6	3300 Level
11	Jumbo Drill	○	15.5	107.5	19.0	23.9	21.2	111.5	17.6	23.0	20.3	124.8	2.4	0	1.2	3300 Level, 552-54 Stope
12	Long Hole Drill I.T.H.	◒	13.5	91.3	3.8	5.5	4.6	93.7	5.4	6.0	5.7	120.0	0	0	0	3400 Level, Waste Pass
13	Long Hole Drill I.T.H.	○	13.5	95.2	13.2	19.4	16.3	97.5	10.4	11.0	11.2	120.3	1.8	4	2.9	3400 Level, Waste Pass
14	Long Hole Drill I.T.H.	○	13.75	97.3	17.1	15.0	16.0	99.65	12.4	14.1	13.25	142.3	27.0	24.2	25.6	3400 Level, 556 Over Cut
15	Diamond Drill	◒	14.25	105.6	8.4	4.1	6.2	108.9	5.2	-	2.51	123.4	+1.7	+3.2	+2.45	3300 Level, 1Cross Cut, Cl.Force 400 gwt.
16	Diamond Drill	◒	12.5	102.9	18.6	23.9	21.2	107.1	18.7	19.4	19.05	124.3	1.9	5.8	3.85	3300 Level, 33-287 E. Drift
17	Diamond Drill	○	13.75	103.5	17.9	7.1	12.5	107.2	17.1	9.2	13.6	120.4	0	0.8	0.4	3300 Level, 33-287 E. Drift
18	Diamond Drill	○	-	108.3	11.5	13.9	12.7	113.3	7.8	14.6	11.2	126.9	0.2	2.9	1.55	3300 Level, 275 Drift
19	Air Plugger(Brk.Cement)	○	13.5	109.8	5.5	10.7	10.1	112.6	8.4	11.5	9.95	148.0	19.2	22.2	20.7	3400 Level, Station
20	Mucking Machine	◒	-	100.5	12.1	13.0	12.5	109.3	5.5	3.9	4.7	148.0	5.1	12.7	8.9	2900 Level, Vent. Drift
21	Mucking Machine	○	-	101.3	7.7	5.7	6.7	110.2	5.8	7.2	6.5	148.0	8.7	13.5	11.1	2900 Level, Vent. Drift
22	Scooptram S-T-8	○	14.0	96.8	9.9	6.6	8.2	96.0	10.4	11.0	10.7	120.4	1.8	4.0	2.9	3400 Level, 564 Over Cut
23	Scooptram S-T-8	○	14.25	98.8	10.5	7.4	8.9	105.3	7.2	5.6	6.4	129.8	2.4	0.4	1.4	3400 Level, 564 Over Cut
24	Scooptram S-T-8	○	-	100.0	11.9	9.3	10.6	107.0	11.1	8.8	9.95	148.0	13.2	20.6	16.9	3400 Level, 552-2 Stope
25	Vent Fans 38" 60 H.P.	○	13.75	93.9	17.4	15.9	16.6	95.4	13.1	10.8	11.95	125.2	6.3	4.1	5.2	3400 Level, 34-278 Ramp
	Mean:		13.76	104.6	13.43	13.22	13.29	108.3	11.44	11.42	11.45	133.11	8.58	9.24	9.03	
	Std. Dev.:		0.66	7.24	4.68	6.03	4.83	7.54	4.64	5.47	4.72	11.24	9.06	9.22	8.94	

Note: ○ Satisfactory; ◒ Good; ● Very Good.

Attenuation tests of different models of ear muffs in OSHA mode.

No.	Equipment	Comfort		L Avg. (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	L Max. (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	L Peak (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	Location
							EAR MUFF - MARK IV									
1	Stoper Dr.-Rock Bltg.	◒	-	108.35	13.4	13.4	13.4	115.8	10.3	0.7	5.5	131.8	1.0	0.5	0.75	3400 Level, 547-1 Stope
2	Stoper Dr.-Rock Bltg.	◒	-	112.0	16.2	13.9	15.0	116.6	13.5	12.8	13.15	148.0	11.3	20.5	15.90	--
3	Vent. Fans, 38" 60 H.P.	●	14.0	101.7	23.2	24.8	24.0	104.35	17.4	20.5	18.95	124.3	4.3	6.3	5.3	3400 Level, Ramp
							EAR MUFF - MARK V									
4	Jumbo Drill	◒	14.0	105.6	14.0	22.4	21.5	108.7	20.2	22.4	21.3	148.0	17.5	24.4	20.95	3400 Level, 543 Stope
							EAR MUFF - DAVID CLARK									
5	Jack Leg AL-60 Drill	◒	-	109.8	19.5	10.7	15.1	118.15	16.3	11.8	14.05	148.0	14.6	10.5	12.55	3900 Level, Vent. Drift
6	Diamond Drill	●	15.0	106.45	19.5	22.8	21.1	109.15	6.2	18.0	12.1	124.5	4.4	4.6	4.5	3300 Level, 1 Cross Cut
							EAR MUFF - BILSOM									
7	Scooptram S.T. 8	●	13.5	97.4	17.9	15.8	16.8	106.3	6.9	9.1	8.0	148.0	7.6	20.0	13.8	3400 Level, 564 Stope
							EAR MUFF - M.S.A. PELTOR (H7)									
8	Mucking Machine	◒	-	97.05	9.7	19.1	14.4	110.2	7.8	17.9	12.85	148.0	10.8	10.9	10.85	

Note: ○ Satisfactory; ◒ Good; ● Very Good.

Attenuation tests of different models of ear muffs in ISO mode.

No.	Equipment	Comfort		L Avg. (dBA)	Attenuation (dBA)			L Max. (dBA)	Attenuation (dBA)			L Peak (dBA)	Attenuation (dBA)			Location
					L.S.	R.S.	B.S.		L.S.	R.S.	B.S.		L.S.	R.S.	B.S.	
								EAR MUFF - MARK IV								
1	Stoper Dr.-Rock Bltg.	◒	-	113.1	16.1	17.6	16.8	119.2	15.9	15.9	15.9	134.2	9.9	5.2	7.55	3600 Level, 547-1 Stope
2	Stoper Dr.-Rock Bltg.	◒	-	110.0	9.1	8.8	8.9	115.2	11.6	7.0	9.3	143.65	7.2	15.0	11.00	3400 Level
3	Vent. Fans, 38" 60 HP	●	14.0	100.1	18.1	19.0	18.5	105.25	11.6	18.3	14.95	125.35	9.3	0.6	4.99	3400 Level, Ramp
								EAR MUFF - MARK V								
4	Jumbo Drill	◒	14.0	104.5	20.8	21.5	22.1	108.8	23.4	19.8	21.6	144.6	27.0	13.6	20.3	3400 Level, 543 Stope
								EAR MUFF - DAVID CLARK								
5	Jack Leg A.-60 Drill	◒	-	114.15	18.5	21.2	19.8	120.0	17.2	22.2	9.6	148.0	9.8	5.4	7.6	3900 Level, Vent. Drift
								EAR MUFF - BILSOM								
6	Scooptram S.T. 8	●	13.5	120.0	10.8	15.2	13.0	103.65	9.4	14.0	11.7	148.0	19.1	14.1	16.6	3400 Level, 564 Stope
								EAR MUFF - H.S.C. PELTOR (H7)								
7	Mucking Machine	◒	-	99.85	11.7	17.9	14.8	109.6	8.3	2.4	5.35	145.3	9.0	9.6	9.3	2900 Level, Vent. Drift

Note: ○ Satisfactory; ◒ Good; ● Very Good.